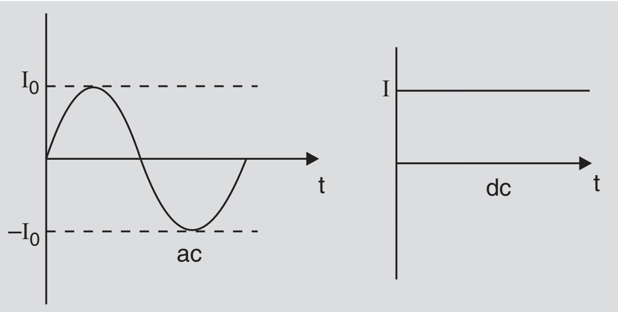
17. Magnetic Effect of Electric Current

- Magnet is a naturally occurring or artificially designed material which has a peculiar property of attracting some materials like iron, nickel and cobalt, called magnetic materials.
- Magnets also have a directional property due to which a magnetic bar when suspended freely always stays in north-south direction. In this situation the end of the magnet which points towards geographical north is called north pole and the one which points towards south is called south pole. The directional property of a magnet is explained by visualizing a large magnet inside the earth with its north pole near the geographical south pole of the earth and vice versa.
- Directional property of magnet is being utilized by navigators for finding direction using a magnetic device called magnetic compass.
- The two poles of a magnet are inseparable and like poles repel each other while unlike poles attract each other.
- Electricity and magnetism were considered two separate phenomena, until, in 1820 Dutch Scientist HC Oersted found that when current is passed through a conductor a magnetic needle lying alongside shows a deflection. Thus magnetism is now seen as a magnetic effect of electric current.
- When direct current is passed through a cylindrical coil of wire (called solenoid), it behaves like a magnet. The strength of the electromagnet depends on: the number of turns per unit length in the coil, the strength of current and material of the core inside it. Again, if the core is of soft iron the magnetism goes as soon as the current is switched off, however, if the core is of material like carbonized steel magnetism stays even when the current is switched off.
- Electromagnets are used in many electrical devices like electric bell, telegraph, magnetic cranes etc.
- A current carrying conductor placed in a magnetic field (i.e., near a magnet) experiences a force, the magnitude of the force is given by $F = BIl\sin\theta$, where B = strength of the field, I = current, l = length of the conductor and θ the angle that the conductor makes with the direction of the field (which is always taken from north to south pole of the source magnet).
- The direction of force experienced by a current carrying conductor placed in a magnetic field is given by 'Fleming's Left Hand Rule', according to which if we stretch the fore finger, the central finger and the thumb of our left hand at right angles to each other and hold it in such a way that central finder points in the direction of current, fore finger in the direction of magnetic field, then the thumb will point in the direction of force.
- A coil of wire when placed in a magnetic field experiences several forces due to which it tends to rotate. The tendency of rotation in the coil is measured in terms of a physical quantity called torque. Due to this torque the current carrying coil may be set into continuous rotatory motion. This is the principle of electric motor–the device which converts electrical energy into mechanical energy and is basic unit used in electric fans, irrigation pumps etc.
- Faraday discovered the phenomenon of electromagnetic induction, according to which a current is induced in a coil when the strength of magnetic field associated with the coil is changed. The current remains in the coil till the change in magnetic field is continued.

Electromagnetic induction is the principle behind electric generators.

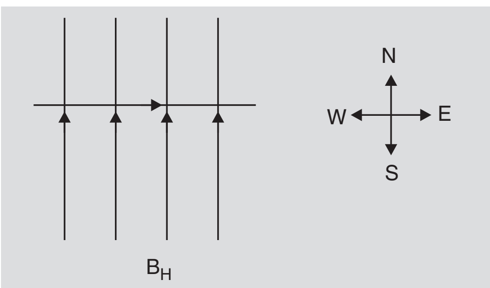
- Depending on the way the energy is tapped out of a generator, the current output that we get may be of two types: ac and dc. ac or alternating current reverses its direction periodically while dc or direct current is unidirectional.



- ac has many advantages over dc, specially the generation, distribution and consumption of ac is much cheaper than dc. True, in some applications like electrolysis and solid state devices we have to use dc but then ac can be easily converted into dc using rectifiers.
- Transformers are devices through which we can increase or decrease the level of ac voltage as required. When voltage is stepped up current is reduced in the same proportion and vice versa. Thus when we step up voltage we reduce current and hence the low current can be sent at lower costs to distant places without much power loss and there using a step down transformer it can be regained and utilized at required level.
- Fuse is a weak link in electric circuits, made of a wire of comparatively higher resistance and lower melting point (such as lead-tin alloy), used to protect the installation. If due to overloading, leakage, or short circuiting excessive current is to flow through the circuit the fuse blows off and saves the installation from the risks of this excessive current. These days we use MCB in place of fuse.
- Earthing in electrical installations is done to protect the operator from getting shock due to leakage of current.

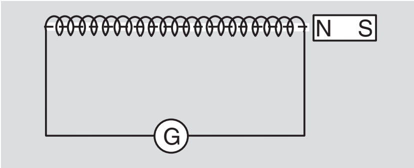
Build Your Understanding

1. At a certain place where the horizontal component of earth's magnetic field is B, a high tension wire lies in E-W direction. Find the direction of current which will correct the sag in the wire due to its own weight.
   Sol: The direction of field is south to north. The force on the wire due to interaction of magnetic field and current is required in upward direciton to counter balance the weight of the wire causing sagging. Applying fleming's left hand rule we determine the direction of current to be west to east.



2. On a 10 cm long cylindrical tube of Cardboard you first wind 100 turns, then 150 turns of insulated copper wire, and then you insert a soft iron rod inside the tube. If same current is passed and you measure the magnetic field each time, in which of the three cases you will have maximum magnetic field and in which case minimum? Explain.
   Sol: Minimum in case 100 turns are wound and core is air. Maximum in case soft iron core is introduced in solenoid of 150 turns. Because more the number of turns per unit length stronger the field and core of magnetic material also increases the strength of the field of an electromagnet.
3. A magnet is moved with respect to a solenoid carrying a galvanometer across it, at a constant speed as shown in Fig. Will there be a deflection in the galvanometer as it moves (i) towards the solenoid, (ii) inside the solenoid, (iii) away

from the solenoid? Will there be any change in the deflection as the speed of the magnet is increased?



Sol: The galvanometer shows deflection when the magnet moves towards or away from the coil due to induced current. If does not show any deflection when the magnet moves inside the coil. When the magnet moves with a greater speed the deflection will be more.

✔ Maximise Your Marks

- Force on a magnetic pole is a redundant concept, because an isolated magnetic pole can never be obtained. We always talk in terms of force due to magnetic field on a current carrying conductor or on a charged particle.
- Any plot of magnetic field lines is always a composite field of the magnet as well as that of the earth. Magnetic field due to earth at a place may always be considered as uniform, pointing south to north.
- Step up transformer build up ac voltage, they do not work on dc, because, for induced voltages changing magnetic field is required. But this does not mean that transformers build up energy. What they gain in voltage they lose in current. In whatever ratio voltage increases in the same ratio current in the output decreases.

i.e., $\dfrac{V_{\text{output}}}{V_{\text{input}}} = \dfrac{I_{\text{input}}}{I_{\text{output}}}$

- In Indian standards the ac that we get in our households is at 220 volts, 50 hertz frequency. But the ac that they get in USA is at 110 volt, 60 hertz. Generators in these countries are constructed accordingly.
- Many of the appliances in our houses which are based on heating effect can be safely used on ac as well as on dc. But the appliances that are based on magnetic effect have different construction for ac and dc and dc appliance can not be used on dc or vice versa.
- Fuse are rated for current. Take care to use proper fuse always. A 15 A fuse should not be used on a 5 A line or conversely 5 A fuse should not be used on a 15 A line. Can you explain, why?

★ Stretch Yourself

1. Write four precautions you will use in laboratory while working on electric line and electrical applicances.
2. Why should you always put your fuse and switch on phase wire only?
3. What can you do to save electrical energy?

? Test Yourself

1. How will you check whether iron bar is a magnet or not? You can do whatever you like with the bar but cannot use anything else for your activity.
2. Why can't two magnetic field lines interest each other.
3. Draw a diagram to show the relative position of earth's geographic axis and magnetic axis.
4. A wire is stretched over a magnetic needle parallel to its magnetic axis. A variable frequency ac source is connected across the wire. How will the deflection of magnetic needle change as we pass current keeping current constant and increasing the frequency gradually.
5. Distinguish between: (i)ac and dc, (ii) Electromagnet and permanent magent.
6. Describe the construction and working of an electric bell with the help of a neat lablled diagram.